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Proceedings of The Third Polar Diatom Colloquium Canadian Museum of Nature Ottawa, Ontario, Canada August 5-10, 1990

M. Poulin (Editor)

Department of Fisheries and Oceans
Communications Directorate
200 Kent Street
Ottawa, Ontario
K1A 0E6

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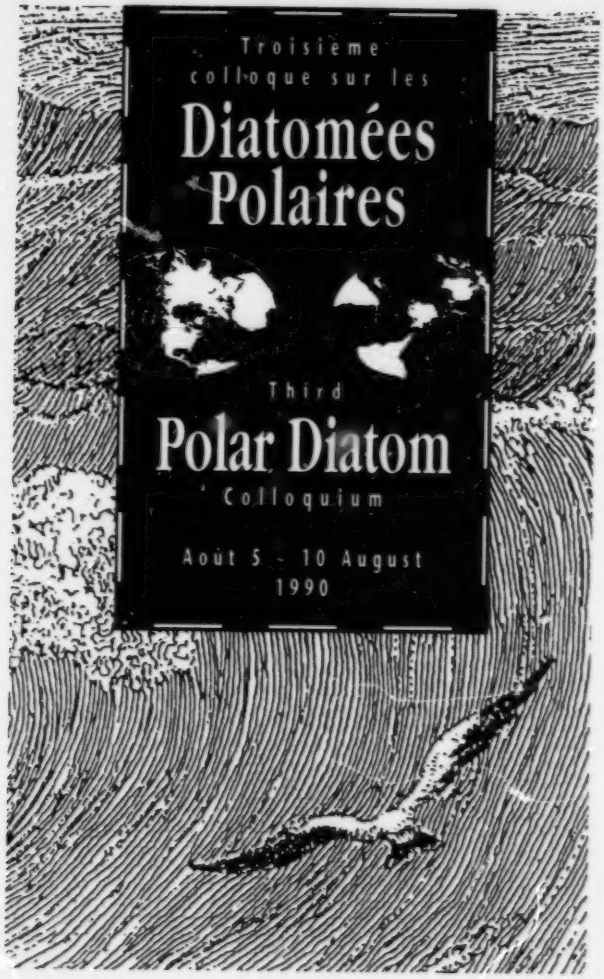
Proceedings of the Third Polar Diatom Colloquium

Canadian Museum of Nature, Ottawa, Ontario, Canada
August 5 - 10, 1990

Edited by

M. Poulin

Canadian Museum of Nature
Botany Division
P.O. Box 3443, Station D
Ottawa, Ontario
K1P 6P4 Canada



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ABSTRACT

The Third Polar Diatom Colloquium was hosted by the Canadian Museum of Nature, Section of Phycology, at the Victoria Memorial Museum Building, Ottawa, Ontario, on August 5-10, 1990. The colloquium was divided into microscopic sessions, dealing with taxonomic problems related to *Nitzschia*, *Navicula* and allied genera, and *Chaetoceros*, and thematic sessions on methods, generic concepts, limiting factors, mechanisms of sedimentation, and ice-water interactions in which group discussions and oral presentations were made.

The proceedings consist of 28 abstracts/summary reports and two session reports, a brief summary on microscopic sessions, a list of cited references, a list of participants and a list of other participants at the two previous meetings.

RÉSUMÉ

Le Troisième colloque sur les diatomées polaires s'est déroulé du 5 au 10 août 1990 à l'Édifice commémoratif Victoria, Musée canadien de la nature, à Ottawa, Ontario, à l'invitation de la section de la phycologie. Le colloque était organisé en deux parties: des sessions de microscopie permettant de résoudre des problèmes taxonomiques chez les genres *Nitzschia*, *Navicula* et *Chaetoceros*, et des sessions thématiques dans lesquelles des débats-discussions et des présentations orales ont été faits sur les sujets suivants, méthodologies, concepts génériques, facteurs limitants, mécanismes de sédimentation et interactions à l'interface glace-eau.

Le compte-rendu contient 28 résumés/rapports sommaires et deux rapports de session, un bref rapport des sessions microscopiques, une liste bibliographique des documents mentionnés, une liste des participants à laquelle s'ajoute une autre liste de participants aux deux précédents colloques.

POLAR DIATOM COLLOQUIUM

The Polar Diatom Colloquium was conceived during a workshop at the Eighth Symposium on Recent and Fossil Diatoms in Paris, August 27-September 1, 1984. At that time, it was decided there were many problems with regard to the taxonomy and ecology of polar diatoms and it would be useful to convene a group of polar diatom researchers to study some of these questions. As a result, the first Polar Diatom Colloquium was held before the Ninth Symposium on Recent and Fossil Diatoms at Bristol in 1986. One problem in particular, that of standardizing the taxonomy of polar diatoms, was the main theme of the meeting. A second colloquium, still stressing taxonomy, was held at the Alfred-Wegener-Institut für Polar- und Meeresforschung in Bremerhaven in 1988. The third colloquium was held at the Canadian Museum of Nature, in Ottawa, August 5-10, 1990.

The Polar Diatom Colloquium is a forum to:

1. Increase communication and scientific interaction between researchers interested in polar regions by addressing issues common to biologists, geologists, and ecologists;

2. Synthesize the current state of scientific research pertaining to diatoms in polar regions and determine questions to be answered to advance scientific efforts in polar regions;

3. Act as a scientific network to provide information on current and future research efforts in polar regions and to integrate scientific efforts.

To meet these objectives, the Organizing Committe for the Third Polar Diatom Colloquium proposed:

1. Sessions focused on current taxonomic concerns that could be addressed by hands-on microscope work coordinated by a teacher-of-the-day;

2. Panel/round table discussions on specific themes addressing the current state of the art and suggesting questions for future research;

3. Production of written reports and review manuscripts for publication in the scientific literature.

Microscopic Work

Mornings were devoted to microscopic work. All participants were asked to bring prepared slides and/or preserved material to share with the group. The teachers-of-the-day presented overviews of their taxonomic group(s); discussed the species composition and distribution of the group(s) in polar regions; and suggested possible future research needs. The teachers indicated the taxonomic groups likely to be

encountered in samples they brought; acted as experts on their group(s); and pointed out taxonomic inconsistencies between habitats and geographical regions.

Thematic Sessions

Afternoon sessions dealt with topics specifically targetted by the Organizing Committee and chaired by one or two leaders. The format of these sessions varied and included both formal and informal individual presentations and group discussions. The leaders were asked to address the state-of-the-art for their topic, point out limitations, and suggest possible future directions for research in polar regions. These sessions are summarized here.

PROGRAM OF THE THIRD POLAR DIATOM COLLOQUIUM

Hour	Sunday 5 August	Monday 6 August	Tuesday 7 August	Wednesday 8 August	Thursday 9 August	Friday 10 August
0830		Navicula *Poulin*	Naviculales *Poulin*	Nitzschia *Medlin*	Chaetoceros *Stockwell*	Final report *Baldauf*
		LM	LM	LM	LM	
1200			**LUNCH BREAK**			
1300	Welcome *Director* Organization *Horner*	LM	LM	LM	LM	Free time
1330	Methods *Horner*					
1430		Generic concepts *Harwood* & *Medlin*	Limiting factors *Baldauf* & *Stockwell*	Sediment mechanisms *Leventer* & *Pichon*	Ice-water interactions *De Sève* & *Watanabe*	
1700			**DINNER BREAK**			
1930	Panel	Panel	Panel	Panel	Panel	Closing dinner Pinch Gallery
2100			**EVENING BREAK**			
			GROUP PARTICIPANTS			
	Bodén De Sève Ferrario Gilbert Håkansson Harwood Jordan Medlin Nikolaev Poulin Stockwell Wasell Watanabe Zielinski	De Sève Ferrario Håkansson Harwood Jordan Medlin Poulin	Baldauf De Sève Ferrario Gilbert Leventer Stockwell Wasell	Bodén De Sève Ferrario Gilbert Håkansson Jordan Leventer Pichon Polyakova Stockwell Watanabe	De Sève Ferrario Horner Leventer Wasell Watanabe	

The people listed indicated their interest in actively contributing to the panels. Other participants also provided information during the sessions.

REPORT ON MICROSCOPIC SESSIONS

The first two mornings, lead by M. Poulin, were devoted to the identification of approximately 30 taxa of the genus *Navicula* and 35 taxa belonging to ten different genera (*Biremis*, *Craspedopleura* an as yet unpublished new genus, *Diploneis*, *Fallacia*, *Gyrosigma*, *Haslea*, *Pinnularia*, *Pleurosigma*, *Stauroneis* and *Stenoneis*) within the order Naviculales. These taxa are well-represented in Arctic sea ice assemblages and slide collections were from Eskimo Lakes, Eclipse Sound, Iqaluit and southeastern Hudson Bay in the Canadian Arctic. The third morning session was conducted by L. Medlin and dealt with several taxa belonging to the genus *Nitzschia*. Samples were from two Arctic locations (1921 at 81°N and Prudhoe Bay) and one Antarctic location (Signy Island). The fourth morning session, chaired by D.A. Stockwell, dealt with the identification of *Chaetoceros* vegetative cells and spores, and *Corethron criophilum*. Sediment and water column samples came from Prydz Bay, Antarctica.

SUMMARY OF THEMATIC SESSIONS

Session 1: Methods
Leader: R. Horner, University of Washington, U.S.A.

Speakers: P. Bodén, N.S. Gilbert, H. Håkansson, D. Harwood, R. Horner, R.W. Jordan, L. Medlin, V.A. Nikolaev, K. Watanabe, U. Zielinski

Many methods have been used to study diatoms and include those for 1) obtaining samples in the field, 2) laboratory analysis of samples, 3) data analysis, and 4) methods for special investigations. This panel was thus divided into four sections.

1. Field methods were discussed by Gilbert (sediment), and Watanabe and Horner (ice biota). To some extent, similar methods have been used to sample both habitats, e.g., special coring devices such as syringes, piston and SIPRE corers, nets, and suction devices. Coring devices may be simple syringes (N.S. Gilbert, pers. comm. 1990; Palmisano et al. 1985c) and sections of plastic core liner (Clasby et al. 1973; Matheke & Horner 1974), or more elaborate instruments such as piston and SIPRE corers and grabs. Some are operated from the surface (SIPRE corers), others by scuba divers working under the ice (combination coring-incubation chambers and syringes). Other coring devices, described for sampling meiobenthos in sediments, might also be tried in the ice (Ruppert 1972; Kirchner 1974). Chain saws have been used to cut blocks of ice (Andersen 1977). Polypropylene jars have been used in the Antarctic to collect the ice platelet layer from the undersurface of congelation ice (Palmisano & Sullivan 1985a; Palmisano et al. 1987). Nets and trawls of various kinds, mesh sizes, and mouth openings have been used to scrape the undersurface of the ice (Carey & Boudrias 1987; Boudrias & Carey 1988; Watanabe 1988) and the upper surface of bottom sediments, as well as in the water column. Suction devices may be syringes, simple scuba diver's "slurp" guns (Legendre et al. 1987), or more elaborate battery-powered devices (Lønne 1988). The kind of sampling gear used depends to some extent on the kind and amount of sample required.

A number of special coring-incubation chambers have been devised that can collect samples and/or be used as incubators for productivity measurements (Clasby et al. 1973; Schrader et al. 1982; Herman 1987), or be incubators for samples collected using surface sampling devices, such as SIPRE corers or chain saws (Booth 1984; Andersen 1977). Other samplers have been devised to collect water immediately under the ice (Rochet et al. 1985; Maestrini et al. 1986), while a special probe has been used in the Antarctic to collect interstitial (pore) water (G. Dieckmann & C.W. Sullivan, pers. comm. 1990).

2. The only laboratory methods discussed involved making slides from sediment material. Håkansson reviewed methods from the literature and pointed out that Kützing (1844) heated samples and was already using chemicals, such as nitric and sulphuric acids, to get rid of organic matter. These methods are generally still in use today, but with some modifications and sometimes different chemicals. Håkansson cleans her material with 10% HCl and 30% hydrogen peroxide in a water bath at 60°C for 30-60 minutes. All of the chemical methods require adequate washing with distilled water to remove the harsh chemicals. For quantitative samples, known quantities of *Lycopodium* spores or microspheres may be added to the material (Kaland & Stabell 1981; Battarbee & Keen 1982).

Bodén and Zielinski described similar methods for obtaining organic and sediment-free diatoms for quantitative analysis, but without the use of microspheres. They also suggested a number of additional references for preparing diatom samples for counting (Abelmann 1988; Abelmann et al. in prep.; Battarbee 1973; Josten & Jeffrey 1978; Laws 1983; Moore 1973; Schrader & Gersonde 1978).

The development of new techniques to recover fossil diatoms from nearly barren glacial sediments will greatly increase our ability to determine the age and character of marine sediments present beneath the Antarctic ice cap. Concentration techniques, described by Harwood, use a combination of fine fraction separation, timed settling, sieving, and density gradients by floating material on heavy liquids such as nontoxic sodium polytungstate. A tall settling tube (ca. 1.7 m height) is set up with the sample in the bottom and water flowing in near the bottom at a constant rate. This sets up convection currents that move fine material up the tube where it is drained onto a sieve. The material on the sieve can then be sorted by size, either in another settling tube or with density gradients and heavy liquids to separate the diatoms from silt particles that have a slightly higher density. Sodium polytungstate is used to produce gradients with downward increasing density from water + sample; 2.0; 2.2; and 2.4 specific gravity. Diatoms are pipetted from the 2.4-2.2 interface.

Very old marine diatoms that might not be sampled otherwise may be obtained from the insides of calcareous concretions and cemented interiors of macrofossils such as ammonites, gastropods, and other molluscs, according to Harwood. These could be sampled in fossil mollusc collections already available in museums to identify rock formations for future study. Knowledge of these very old diatoms may help in timing diatom migration from marine to non-marine environments and will provide much-needed information on changes in diatom assemblages through time.

3. The discussion of data analysis by Jordan reminded us about old problems that need better solutions. For example, how much sample must be counted? What should be counted: whole cells, valve fragments, etc.? What should be done with the data? How should they be interpreted? Should absolute or relative abundances be used in data analysis? Many of these questions have been discussed previously (e.g., Lund et al.

1958; Holmes & Widrig 1956; Venrick 1972; Sournia 1978, chapters 7 & 8). The need for consistency with regard to counting procedures was recognized.

4. One special method, the low temperature scanning electron microscope (LTSEM) (Beckett & Read 1986), was described by Medlin. This involves examining specimens in a frozen, fully hydrated state. Specimens are rapidly frozen in liquid nitrogen and maintained under vacuum until processed. They may be fractured, dissected, retained intact, heated to remove surface water, and/or coated while still frozen and under vacuum. Specimens are transferred to the SEM via a special port and examined on a temperature-controlled stage at -175°C . A conductive heater built into the base of the cold stage may be used to etch uncoated specimens inside the SEM. The LTSEM provides a mechanism whereby samples can be quickly immobilized and stabilized so that spatial and morphological relationships are maintained. Liquid nitrogen penetration is instantaneous compared with chemical fixation so there is very little distortion of the specimens. Ions can be immobilized for elemental analysis. Repeated fractures can be done to determine internal structure. The limitations of the method include 1) no long term sample storage without special equipment, 2) resolution is not very good for fine detail, and 3) it is not good for large, soft-bodied specimens (animals), but is better with botanical material.

The use of an underwater microscope for sampling was discussed by Gilbert. It was built from a Shimadzu compound light microscope by removing the rotating objective lens assembly and eyepiece unit from the stand and putting it in a sealed, chrome-plated brass housing. To bring the eyepiece closer to the user's eye, the perspex faceplate of a diving mask was modified to include an inverted port. Lighting was provided by an attached portable underwater torch. Magnification of this microscope was changed by using different objective lenses and/or eyepieces. This instrument, used by Kennelly & Underwood (1984) to sample under a sublittoral kelp bed, might be useful for divers to make quick, on-the-spot assessments of cells in both the bottom ice and sediment assemblages.

During these discussions, it became obvious that there have been very few real comparisons between methods in many cases and the limitations of most methods have not been discussed adequately. Better descriptions are needed in the literature for many methods, especially if an old method has been modified in some way. Frequently, it is the little modifications/tricks, e.g., melting ice cores in large volumes of filtered seawater to prevent osmotic shock (Garrison & Buck 1986), that will be useful to other investigators, but these are the things most often not described. Preservation methods were discussed briefly, but the only consensus was that glass jars are preferable to plastic ones for storing diatom samples. It also became obvious that we should look in the literature more often and more extensively. For example, we should not limit our reviews only to marine or freshwater literature, but should look at both, because problems are often similar.

Session 2: Generic Concepts

Leaders: **D. Harwood, University of Nebraska-Lincoln, U.S.A.**
L. Medlin, University of Bristol, U.K.

Speakers: D. Harwood, L. Medlin, R.W. Jordan, H. Håkansson, M. Poulin, M. Ferrario, P. Bodén, V.A. Nikolaev, J. Kingston

D. Harwood: Introduction
What is a genus from a paleontologist's perspective?

This session involved informal presentations and discussions on a variety of topics centering on generic concepts. D. Harwood and L. Medlin introduced the session with the general question "what is a genus?", from the standpoints of a paleontologist and a biologist, respectively. R. Jordan provided perspectives on generic limits of allied groups of microalgae, with examples from calcareous nanoplankton, silicoflagellates and dinoflagellates. H. Håkansson reviewed the nomenclatural history and division of several non-marine centric diatom genera. D. Stockwell described the limits within *Chaetoceros* and *Corethron*. V. Nikolaev described several genera within the "primitive" family Pyxidiculaceae. M. Poulin discussed several genera within the Naviculales. R. Jordan reviewed recent taxonomic changes within the genus *Rhizosolenia*, and criteria used to erect the new genus *Proboscia*. P. Bodén illustrated the variation within a group of species of *Thalassiosira*, i.e., *T. oestrupii*, *T. praeoestrupii*, and *T. nativa*. M. Ferrario reviewed *Triceratium* and *Trigonium*. J. Kingston concluded the session with a critique of systematic concepts in Round et al. (1990). Summaries of several of these discussions are presented below. While most of the session focused on the genus, discussions frequently drifted to broader issues of classification involving families, species, and subspecies.

A general observation resulting from discussions and presentations during this session was the apparent difference between the perception of generic limits by biologists and paleontologists. This difference is manifest in both philosophical considerations and research applications toward different goals with different degrees of resolution and, results in part because most biologists focus on one time-plane, the present, whereas paleontologists study diatom records from a near-infinite number of time-planes. Thus, many different diatom genera are known to paleontologists, and their concept of a particular genus is broader than that of a biologist because it also includes many extinct species. The historical record afforded by biostratigraphy illustrates the gradual drift of generic characters through time in other groups. The fossil record also aids the separation of related genera by recognizing the timing and origin of morphological innovations that give rise to new genera.

Information from the fossil record, combined with cladistic studies of modern and fossil species, will provide greater understanding of the natural relationships between various taxonomic levels. The result should be a more natural foundation to diatom classification. Although considerable advances have been made recently through detailed SEM study, the paucity of such studies and gaps in the fossil record limit our approach to such a system, which reflects true evolutionary relationships. Due to preservational selectivity, the above discussion certainly over-emphasizes the role of the fossil record in deciphering the historical development of diatoms. However, this over-emphasis is intended to counter-balance the treatment in Round et al. (1990), where the value of the fossil record is not fully realized, and is in fact passively suppressed.

The need for a highly refined division of taxa at species, subspecies, and varietal levels is evident in modern ecological studies. While it is beneficial to monitor all available information, the undue lumping of taxa at all levels results in the loss of morphological and ecological information. Many detailed studies of modern diatom assemblages rely heavily on SEM observation. However, time and resources often inhibit similar detailed examination of fossil material and most routine geological work is performed with the LM. In most cases SEM studies have clarified and resolved structures seen originally with LM. SEM studies have better indicated the relationships between taxa based on

morphologically similar structures. For the development of a natural classification system, we need as much morphological information as we can collect from both LM and SEM.

There was a clear consensus that many problems still exist within the present classification system. Participants cited examples where new genera should be erected and all agreed that we need more genera overall. Many genera should be separated, resurrected from synonymy, or newly described. Detailed SEM documentation of morphological structures of many known taxa is needed, with attention to structures on the mantle, girdle bands, etc. Information from wall structure, cell biology, life history, and other aspects of living diatoms will help clarify generic relationships, but may have limited use in fossil taxonomic diatomology. New advances will also come from newly discovered fossil deposits that fill in missing ages, e.g., the interval between the Albian (Lower Cretaceous) and the Campanian (Upper Cretaceous) where only a few genera are common to both time periods (Gersonde & Harwood 1990; Harwood & Gersonde 1990). Time represented in this gap witnessed the evolution of many modern genera. Filling this gap, and others in the Paleogene, will certainly improve our understanding of generic and higher taxonomic level evolutionary history and the development of key morphological structures that guide our present taxonomic divisions.

In providing for a natural system, all members of a genus must have evolved from one ancestral lineage. This emphasizes the need for combined biostratigraphic-cladistic studies. Determining which character, or set of characters, define a genus should have a foundation in the stability of these characters through time, although some tolerance for evolutionary drift should exist. It should be apparent that although a collection of species defines the characteristics of a genus, the species composition of the genus changes through geologic time. The Oligocene genus *Asteromphalus*, for example, has virtually no species in common with the Miocene genus *Asteromphalus*. A diatomist specialized in Miocene diatoms will have different generic concepts than those of an Oligocene specialist. Therefore, generic definitions should include a single lineage. We all strive for a natural system of classification, with generic and higher level divisions based on evolutionary relationships and major innovations of form and structure.

Several questions were raised, but remained unanswered.
1) Are only seven major taxonomic levels sufficient to divide a highly diverse group such as the diatoms? Should other levels be introduced for certain groups that experienced explosive radiations?
2) Many diatoms are currently assigned to "form genera", particularly spore valves and diatoms of uncertain affinity. Should these names be retained, as allowed by the International Code of Botanical Nomenclature, even when spores can be assigned to a vegetative form? If a spore generic name has priority of valid publication over a vegetative cell generic name, should the spore name replace the widely used vegetative one?

Our discussion highlighted taxonomic differences between biologists and paleontologists, with several diatomists who study only living assemblages stating their desire to view, during the next colloquium, examples of the diversity offered by the fossil record. Although numerous advances have been made recently in developing a natural system of classification, there is still a clear need for the erection of more genera, for continued documentation of diatom morphostructures, and for closer interaction between paleontologists and biologists in addressing these issues.

L. Medlin: What is a genus from a biologist's perspective?

Round et al (1990) have defined a genus as a cluster of species between which differences are not large enough to allow further subdivision. Characters used to define a genus should be qualitative not quantitative and should include the presence not absence of features. A range of variation in each feature should be expected and not all members of a genus will necessarily possess all features. Controversy exists concerning the standardization of criteria used at each taxonomic level. This may be variable within different groups and undoubtedly reflects the state of our knowledge of certain groups that allows taxonomists either to over or under classify. Certain frustule features are very basic and probably represent major division points. These include areolae, raphe/sternum, cingulum, processes, spines, and pore fields.

R.W. Jordan: Generic concepts in other allied groups of testate microalgae

The generic concept was considered for other groups of algae using dinoflagellates, silicoflagellates, and coccolithophorids as examples. The conclusions drawn from this brief overview suggest that on the generic level, test morphology is still the most important character used in the taxonomy of testate microalgae. Whilst current research is now heading towards phylogenetic studies using other criteria (e.g., RNA, chloroplast and flagella structure), evolutionary classification systems based on these characters are still premature. Meanwhile, it is important that taxonomies based on test morphology should still be used and improved. Life-cycle studies, including sexual cycles, vegetative and survival forms, are recognized as probably the most important work for the near future.

As seen with many algal groups, there is a need to relate cyst stages to their vegetative stages and to be able to recognize changes in test morphology occurring under different conditions. For example, parallel taxonomies occur for dinoflagellate cysts, and vegetative cells, for holococcolith- and heterococcolith-bearing cells in coccolithophorids, and for vegetative and resting spore cells in diatoms. In addition, it is necessary to understand how genera have changed with time in order to gauge the time variability exhibited by a single genus, and to be aware of transitional forms that may bridge the gap between closely related genera.

R.W. Jordan: A critical review of the polar representatives of the Rhizosoleniaceae

Until recently the genus *Rhizosolenia* contained several species that lacked the classical features of the type species, *R. styliformis*. Many of these have now been assigned to new genera.

1. At least three living species are presently recognized as having a truncate proboscis, on which a ring of spinulae and a longitudinal slit are located. The genus *Proboscia* was erected by Sundström (1986) to include only the type species *P. alata* (=*R. alata*), although he recommended the transfer of other species including *R. truncata* and *R. inermis* that are now considered to be valid members of *Proboscia* (Priddle et al., In press; Jordan et al., In press a).
2. In the fossil record, some species bearing truncate probosces have been transferred to *Simonseniella* (Fenner, In press), however, both the type, *S. barboi* (=*R. barboi*), and *S. curvirostris* (=*R. curvirostris*) share certain characters with *Proboscia*.
3. *Rhizosolenia calcar-avis*, a species with a convoluted internal labiate process and a seam-like marking running down the valve length, but lacking otaria and claspers, is now the type of a new genus, *Pseudosolenia* (Sundström 1986).

4. Sundström (1986) also recommended that certain species, including *R. setigera*, *R. rhombus*, and *R. stolterfothii*, be removed from the genus *Rhizosolenia sensu stricto* and placed in new genera. Until further work is done on these taxa, they are still affiliated with *Rhizosolenia*.
5. The freshwater species, *R. eriensis*, has now been transferred to a new genus, *Urosolenia* (Round et al. 1990).

It is important that these problems in taxonomy are overcome and that fossil representatives are studied in further detail so that phylogenetic relationships can be better understood.

H. Håkansson: Grouping of species in the genus *Cyclotella* or different genera?

The genus *Cyclotella* comprises a large complex of centric diatoms which have been divided several times into different groups (Schütt 1896, Lowe 1975, Serieyssol 1984). Lowe (1975) and Serieyssol (1984) made their grouping after electron microscopic investigations only. All species in the genus *Cyclotella* have two different structures on the valve face: a structured or unstructured central area and a striated and/or alveolate marginal area. Therefore, three morphologically different groups can be recognized in LM:
1. *Cyclotella* species with a structureless central area with possibly one to several central fultoportula.
2. *Cyclotella* species with a structured central area and "shadowlines" (schattenlinien) in the marginal area.
3. *Cyclotella* species with a structured central area but without "shadowlines" in the marginal area.

For the nomenclatural aspect on *Cyclotella*, Kützing (1834) divided the genus *Frustulia* Agardh (1827) into two subgenera giving one the name *Cyclotella* with only one species: *Frustulia operculata* Agardh (=*Rhopalodia operculata* (Agardh) Håkansson). At the same time he applied the name to specimens from Tennstaedt, Erfurt, Germany (Kützing 139, BM 17986) which belong to the species to which the name *Cyclotella operculata* has been applied ever since. Brébisson (1838) elevated *Frustulia* subgenus *Cyclotella* Kützing to generic rank as *Cyclotella* (Kützing) Brébisson. As conservation was necessary if *Cyclotella* was to continue to be used in its traditional sense, Håkansson & Ross (1984) proposed that Kützing's Tennstaedt material should be the conserved type of the generic name *Cyclotella* (Kützing) Brébisson, and this has been accepted (Greuter et al. 1988, p. 119). Håkansson (1989) showed that the name *Cyclotella tecta*, newly given by Håkansson & Ross (1984) for the species incorrectly known for so long as *Cyclotella operculata*, is in fact conspecific with *Cyclotella distinguenda* Hustedt.

The type species of the genus *Cyclotella* belongs to the here-mentioned group 1. Should this be a genus of its own and the other two groups (2 and 3) new genera? As in several (or all) genera, the value of taxonomic criteria needs continuous research. This concerns their selection as well as their variability. Further, it is not clear if the presence or absence, and the number and form of the central fultoportula are taxonomic or ecological criteria, or if they belong to the variability of the taxa (*C. striata-meneghiniana-madden-caspian* complex, as well as *C. bodanica-radiosa-stelligera* complex). Very little is known about the variability of the valve structures during the life history. There is still more research needed to delineate with certainty the different groups into new genera.

M. Poulin: Some considerations about the Naviculales

In the classification of diatoms proposed by Round et al. (1990), the Bacillariophyta is comprised of 3 classes: the Coscinodiscophyceae (centric diatoms), the Fragilariophyceae (araphid pennate diatoms) and the Bacillariophyceae (raphid pennate diatoms). This latter is characterized by having feather-like striae and either a raphe or a sternum, and contains 2 subclasses: the Eunotiophycidae (one order) and the Bacillariophycidae (10 orders). The Naviculales, which has the highest number of genera and species occurring in Arctic ice algal assemblages, can be differentiated from the Lyrellales and the Mastogloiales by the lack of large, pore-like areolate striae not occluded by hymenes; from the Dictyoneidales by the lack of complex ornamentation consisting of an inner layer of minute poroids and an outer layer of coarse areolae; from the Cymbellales and the Thalassiophysales by the lack of dorsiventral cells; from the Achnanthales by having isovalvate frustules; and from the Bacillariales, the Rhopadiales and the Surirellales by the lack of a fibulate and keeled raphe system.

Within the Naviculales, several taxonomic ranks have been proposed (Round et al. 1990). First, the Naviculaceae, which has the highest number of taxa in Arctic ice algal assemblages, now represents a fairly well circumscribed group (e.g., *Navicula*, *Haslea*) mainly characterized by linear or lanceolate valves with uniseriate striation consisting of external, apically elongate, slit-like areolae. As an example, the genus *Navicula* has evolved considerably since Hustedt or Patrick's time so that several old sections have now been removed and raised to generic ranks: the *Lyratae* has been split into *Lyrella* and *Fallacia* (Karayeva 1978; Round et al. 1990), while the *Punctatae* has been divided into *Petroneis* and *Cosmioneis* (Round et al. 1990). After a study on the typification of *Navicula* (Cox 1979) and a refurbished definition of the genus (Round et al. 1990), *Navicula* can no longer be considered a "melting pot" group.

Pinnulariaceae, the second important family, is characterized by linear to elliptical valves with multiseriate striation, that is usually alveolate and occasionally interrupted by lateral sterna. In LM, the specimens appear as large cells with structureless striae due to the minute size of the poroids. In Arctic sea ice, marine *Pinnularia* are not dorsiventral (Round et al. 1990), but two clusters co-exist (*quadratarea* and *semiinflata*) and differ from one another by the lack of external polar raphe fissures and an asymmetry to the apical plane of the valve structures for the latter.

The resurrected Pleurosigmataceae contains some endemic taxa of ice algal assemblages (e.g., *Gyrosigma*, *Pleurosigma*) and is recognizable by having sigmoid valves like the raphe system, ornamented by areolae arranged in longitudinal and transverse striae, or in decussate rows, with prominent central bars internally bordering the nodule (Cardinal et al. 1989; Poulin, In press).

The next 4 families discussed are represented by only one or two species. The Berkeleyaceae (*Stenoneis*) is featured by linear or lanceolate valves with a uniseriate striation and a raphe-sternum which is central and often thickened internally. The validity of *Stenoneis* is questioned by Round et al. (1990) who relate it to *Climaconeis*. However, *Stenoneis* is clearly distinguished from *Climaconeis* by having few plastids, no craticular bars, and the occurrence of short ridges bordering the external proximal raphe branches (Poulin 1986, Round et al. 1990). The Diploneidaceae (*Diploneis*) is featured mainly by a complex striation and continuous longitudinal canals on each side of the raphe. The Sellaphoraceae (*Fallacia*) possess naviculoid valves with lyre-shaped

lateral sterna and a conopeum. The Stauroneidaceae (*Stauroneis*) has lanceolate to elliptical valves with a prominent thick stauros.

The classification proposed by Round et al. (1990), especially the section on raphid diatoms, is very innovative and will help to tighten relationships between groups of genera. The introduction of new families in the Naviculales was done by grouping together closely related genera based on distinct morphological criteria as well as plastid structure. As an example, the separation of the Diploneidaceae and the Pleurosigmataceae from the old concept of the Naviculaceae is based on a series of valve features that are specific to each of these families.

In future investigations, diatom taxonomists will perhaps have to perform biochemical analyses in order to clarify relationships within species or between species clusters. Will they also have to look at the chloroplast genome? But all these techniques would have to be used in conjunction with morphological data obtained through LM and SEM.

M. Ferrario: Some considerations of the ocellar structure in biddulphioid diatoms

Currently the biddulphioid term refers to genera in the Centrales that are characterized by having valves which are primarily bipolar, or secondarily tripolar, multipolar, or circular with ocelli or pseudocelli and poroid or loculate areolae. Generic and family limits within these groups have been revised by Ross & Sims (1971), Simonsen (1972a, b, 1979), Ross et al. (1977), and Hoban (1983).

Here, I consider structures that characterize two biddulphioid families. From an analysis based on ocellar structure, one can infer that the presence of pseudocelli or costate ocelli characterizes the family Biddulphiaceae, while the presence of ocelli is characteristic of the family Eupodiscaceae.

Syvertsen & Hasle (1983) considered a costate ocellus to be an intermediate structure between an ocellus and a pseudocellus. However, their photographs of the genus *Eucampia* Ehrenb., and the costate ocellus in *Cerataulina* Peragallo (Hasle & Syvertsen 1980), as well as my own observations, suggest that the costate ocellus is not an intermediate structure, but a type of ocellus. In addition, the pseudocelli of *Hemiaulus* Ehrenb. (Ross et al. 1977) are in fact ocelli, very similar to those in *Odontella rostrata* (Hustedt) Simonsen or *O. litigiosa* (V.H.) Hoban (polymorpha phase)(Hoban et al. 1980, Sar 1989).

Therefore, the definition of an ocellus should be modified and enlarged to encompass true ocelli, ocelli of the costate type, and variations between them (e.g., *Eucampia* and *Cerataulina*). If this is taken into account, the genera *Eucampia*, *Cerataulina* and *Hemiaulus*, presently in the family Biddulphiaceae should be transferred to the family Eupodiscaceae.

P. Bodén: Variation within a group of *Thalassiosira*

A distinct new variety of *Thalassiosira praeoestrupii* has been observed, *T. praeoestrupii* var. *minor*. This variety is distinguished by its generally smaller size and by the location of the labiate process at the valve margin. The labiate process is not visible in the LM because of its location. The taxonomic placement of this form in the *T. oestrupii* group is based on SEM observations. In contrast to *Thalassiosira nativa*, which has a similar areolation pattern and location of the labiate process, *T. praeoestrupii* var. *minor* (as all forms in the *T. oestrupii* group) possesses only one strutted process in the center of the valve. Another character, seen in the SEM, that separates the *T. oestrupii*

group from *T. nativa*, is the number of strutted processes around the valve margin. Specimens of the *T. oestrupii* group have 2-3 strutted processes in a quarter of the valve outline, whereas *T. nativa* possesses 5-9 strutted processes. Two other characters distinguishing *T. nativa* from the *T. oestrupii* group are the occurrence of occluded processes and the presence of external tubes on the strutted processes. However, these characters vary from being strongly developed to not being developed at all and probably reflect dissolution.

V.A. Nikolaev: Pyxidiculaceae

A brief presentation addressed the primitiveness of the Pyxidiculaceae (Gleser et al. 1988).

J. Kingston: Some brief critical comments on Round et al. (1990), "Concepts in diatom systematics"

Round et al. (1990) promote "overall similarity" as the best model for a "natural" diatom systematic scheme, and they stress that the technique of phenetic analysis is preferred to other methods. This view is not supported in the recent evolutionary literature, however, in which phenetics has lost out to the technique of cladistic analysis. The major difference in approach is that phenetics uses all shared characters, while cladistics uses shared *derived* characters. Phenetics can lead to more genetic variability within clusters than cladistics, and cladistics leads to a more natural classification (Kociolek & Stoermer 1986).

Furthermore, although Round et al. (1990) promote phenetics in the strongest language, they do not present any phenetic data using diatoms, nor do they cite any major study that does so. Although they argue against weighting of characters for taxonomy, they weight characters for their own systematic scheme.

Although Round et al. (1990) call for a monograph "of well defined genera", we also need cladistic analysis of poorly defined genera. They argue against regional floristic analysis, but I would argue that such research has provided systematists with some of the crucial raw data that they require. We need more floristic research, not less.

An interesting debate about the proliferation of generic names may be found in Williams & Round (1987) and the critique of this paper by Lange-Bertalot (1989) who argues against it on two grounds. First, he presents data to suggest that some of the characters used are variable, and are not useful for taxonomic separation. Second, he argues philosophically that the proliferation of new names is "not helpful". It seems to me that Lange-Bertalot presents a good argument only in the first instance, and the real message is this: *we need more data*!

Session 3: Limiting Factors
Leaders: J. Baldauf, Texas A&M University, U.S.A.
D.A. Stockwell, University of Texas at Austin, U.S.A.

The format for this panel differed from other sessions in that it consisted of both oral presentations and group discussions. Emphasis during this panel was placed on group discussions in order to 1) determine and rank the limiting factors that act as regulators of species morphology, species abundance, and assemblage composition in high latitudes,

2) determine spatial and temporal scales at which each factor is effective, 3) list tools and methods currently available in evaluating each factor, 4) determine variables that influence each limiting factor, and 5) provide a bibliographical sources (marked with an asterisk * in the reference list) about limiting factors for future evaluation. This establishes a framework of our current understanding of limiting factors in high latitudes, which is by no means complete, yet it does allow identification of gaps and topics requiring extensive scientific investigation.

Speakers: N.S. Gilbert, J.-J. Pichon, J. Kingston

N.S. Gilbert: Annual cycle of chlorophyll and nutrients at Signy Island

Information was presented concerning a long-term study of the water column at Signy Island, Antarctica (Clarke et al. 1988). Temperature, salinity, chlorophyll, and nutrients were measured on a monthly basis for a period of 13 years (1969 to 1982). Two sites in Borge Bay, on the east coast of Signy Island, were chosen for the study: a 6 m site in Factory Cove and a 10 m site in Orwell Bight. Salinity measurements showed little seasonal variation. Temperature showed a slight variation from a winter minimum value of -1.8°C to a summer maximum of +0.3°C.

Water column chlorophyll levels showed distinct seasonal variation and high year to year variation. Winter levels were low (<0.3 mg/m^3), but an annual bloom began each year in late November and peaked in January at a mean of ~20 mg/m^3 chlorophyll. Between 1971 and 1982, peak chlorophyll standing crop varied from 2.2 to 41.6 mg/m^3. The bloom declined rapidly in February, reaching winter levels once more during March.

Nutrients also varied seasonally. Winter levels of nitrate, phosphate, and silicate were high and all showed extensive depletion during the bloom. Nitrate varied much less seasonally, but decreased slightly in summer. A close correlation between the size of the bloom and the extent to which nutrients were depleted was observed and nutrients were thought to set an upper limit to bloom intensity. Bloom intensity could also be correlated with mean wind speed for the months of November and January. Significantly these were the months during which the bloom started and peaked. It was concluded that water column stability greatly influenced the observed yearly variation in bloom size. Comparison of other Southern Ocean data indicated that in inshore areas, phytoplankton blooms are typically more predictable and intense then in offshore waters. Further work at Signy island will include a continuation of the study from the 1988/1989 season.

J.-J. Pichon: Fluxes of biogenic silica corrected by quantitative estimation of dissolution in the southeastern Indian Ocean

A transfer function has been established to quantify the dissolution of diatom silica in Southern Ocean cores. The relationship between the amount of dissolved silica and changes in the diatom specific distribution is based on progressive dissolution of the silica from five core tops, each representing one of the modern diatom assemblages. The amount of dissolved silica was measured for each of the experiments. The resulting 42 samples of the data set of diatom species abundances may be added to a data base of modern core tops containing diatom species distributed over the Southern Ocean (124 samples total). Factoral analysis (Q mode) individualized 4 factors explaining 83% of the variance. The first 3 factors are controlled by surface water properties (summer

SST), the fourth factor is highly correlated with the loss of silica in the reference samples. We quantified the dissolution factor using the correlations. The biogenic silica fluxes accumulated in Holocene sediments from 20 box cores from the southeastern Indian Ocean are corrected by dissolution estimates. The fluxes vary between 0.5-9 g/cm^2/kyrs in the subantarctic zone, of 2.5 and 10 g/cm^2/kyrs between 63°S and 68°S.

J. Kingston: Gradient analysis: recent developments in diatom ecological research

An overview was presented concerning previous and current methods used in diatom ecological research. This presentation was a preview of a similar presentation for the 11th International Symposium on Living and Fossil Diatoms (see abstract O-14, page 57 of the abstract volume). Emphasis of discussion was placed on the use of direct gradient analysis technique of regression (maximum likelihood or weighted averaging) to describe the optimal and tolerances of diatom taxa. These techniques work well for marine phytoplankton, sediment assemblages, and ice algae. They can be used to interpret controlling environmental variables with diatom species data.

Working group discussions

Most of the session was devoted to group discussions on the role of limiting factors as regulators of species morphology, species abundance, and assemblage composition in high latitudes. Group discussions also focused on the question of using diatom species or assemblages as a means to determine specific limiting factors. Limiting factors addressed included: temperature, light (duration, intensity, quality), salinity, nutrients, dissolution, competition, grazing, phytoplankton and zooplankton production, water column stability and advection, wind, sea ice and ice shelves, and dilution. Other limiting factors were mentioned, but without further discussions. These included parameters such as food chain length, transfer efficiencies, thermal influences, turbulence, and diffusion.

Although agreement exists that the above 12 factors may be limiting to the diatom species and assemblages in high latitudes, there was little consensus as to the specific ranking or importance of each factor. The above factors are divided into three groups: GROUP I, temperature, salinity, light and nutrients; GROUP II, grazing, competition and dissolution; and GROUP III, water column stability and advection, dilution, production, wind and sea ice.

GROUP I

Temperature

geographic scales - local to latitudinal, vertical, small scale changes
temporal scales - days to years, gradients with winter, climatic variability (10-100,000 years)
tools - temperature probe, XBT's, CTD, isotopic analysis, indicator species
factors - solar radiation, oceanographic circulation
influence - affects water column stability and circulation patterns
biological - valve morphology, species survival, rate of dissolution
geological - species distribution, rate of dissolution, diagenesis

Although temperature is very important at various scales, it is considered a critical factor at local or smaller scales where it plays a direct role in species distribution and morphology. It is also indirectly important at larger scales (latitudinal or greater) by

influencing ocean circulation and water mass properties. Most of the data concerning temperature result from comparing temperature probe, XBT, and CTD data with horizontal and vertical species distribution. These calibrations are generally based on data from specific geographic locations or individual transects. Minimal effort has been directed at determining the optimal/range of temperature tolerance for specific species or a given assemblage.

From the geological perspective paleotemperature estimates are often inferred from isotopic analysis. Several workers have used the biogeographic distribution of species and their inferred association with specific water masses to determine a qualitative estimate of paleotemperature (e.g., Kanaya 1957). Other workers have attempted to relate modern distributions of species and assemblages present in surface waters and surface sediments to diatom distribution downcore (e.g., Fenner 1977). However downcore changes of the assemblage reflect changing local water mass conditions not necessarily temperature. This factor, combined with other variables such as dissolution and geological vs biological species concepts, reduces the reliability of diatoms as temperature indicators in the geological record.

Specific questions that need to be addressed about temperature include:
1) Do floristic distribution maps accurately reflect temperature?
2) Do we know or can we test the optimal range of a specific species or assemblage? If so, how do you separate out other variables?
3) What is the accuracy of paleotemperature determinations based on isotope calibrations and do changes in isotope values reflect temperature changes?

Light (duration, intensity, quality)

geographic scales - duration (regional/global); **intensity** (local and vertical); **quality** (local through global)

temporal scales - seasonal (early seasonal factor on growth, summer growth inhibitor)

tools - light meter, sediment trap studies, time series analysis

factors - sun angle, meteorological events, local snow cover/depth, regional ice cover/thickness/quality, concentration of particulate matter, volcanic activity, turbidity

influence - valve morphology, species distribution, cyst formation, bloom initiation, light inhibition

biological record - low light/shade adaptation, winter/summer forms

geological record - species composition, winter/summer forms

Light is a critical regulator of diatom species and assemblages. For this discussion, light was subdivided into three variables (duration, intensity, and quality). Each having different limitations on diatoms, as well as acting at different temporal and geographic scales. Of the variables, light intensity was viewed as the most important at local scales, as well as playing a major role with regard to vertical stratification of the water column. Light quality was also important at local scales, and similar to duration, it influences the diatom species and assemblage at regional and global scales. The use of diatom species or assemblages to determine variation in light is problematic at very short time scales (such as days or weeks), but different morphotypes of vegetative cells (i.e. winter/summer forms) allow monitoring of seasonal changes.

Specific questions to be addressed in future research include:
1) What is the accuracy of light measurements?

2) At what scale does light change (i.e. what is the mean variability and can you separate light intensity from light duration)?
3) What is the light tolerance (optimal range) for specific species?

Salinity

geographic scales - local through latitudinal, vertical (intermediate and bottom water)
temporal scales - residence time of a water mass
tools - XBS's, interstitial pore water measurements, salinometers
factors - ice melt, runoff, evaporation, precipitation
influence - density gradients, osmotic regulation
biological record -valve morphology, species distribution
geological record - species composition

Salinity is considered a critical factor because it directly limits diatom production horizontally and vertically at local scales. In high latitudes this is best examplified by the influence salinity changes have on diatom production and distribution as a result of ice melt or runoff. In addition, salinity is important at larger scales (e.g., latitudinal) where it indirectly regulates diatoms by influencing water mass distribution and ocean circulation.

Diatoms preserved in the geological record have been used for paleosalinity indicators. However, this has been at extremely coarse scales such as marine, brackish, and freshwater, rather than at finer scales such as changes in parts per thousand. This higher resolution is necessary, but is prevented by the difficulties with the geological record which include those factors discussed under temperature.

Questions that need to be addressed about salinity include:
1) Are diatom assemblages useful indicators of paleosalinities?
2) What effect does salinity have on morphological change?

Nutrients

geographic scales - local through global
temporal scales - week through seasonal, depends on residence time of water and water cycle, late season limiting
tools - auto analyzer, additional nitrogen and carbon dating needed
factors - meteorological and oceanographical process, biological depletion
influence - valve formation, cell division, morphology, species composition, species abundance

Nutrients are also ranked high with regard to their ability to regulate diatom species and assemblages. Although numerous studies on nutrients and the response of species to specific nutrients have been successful in the laboratory, few investigations have applied these findings to natural settings, thus limiting our understanding of the full impact nutrients may play as limiting factors. No effort was made during the course of these discussions to subdivide nutrients. Several participants expressed concern that silica was an important factor, while others felt silica was definitely overrated and not limiting in high latitude environments.

With the increased emphasis on ocean chemistry and chemical budgets in both modern and past ocean conditions, it becomes imperative that diatom analysis integrate chemical parameters into future studies. For example, can phytoplankton assemblages provide the means to determine nutrient distribution and can this be applied to the sediment

record? In addition, further analysis needs to be done concerning the variability of nutrients in time and space within the modern ocean.

Specific questions include:
1) Can diatoms in the geological record be related to the presence or absence of a specific nutrient?
2) What is the variability of silica in an upwelling environment?
3) Is silica overrated as a limiting factor?

GROUP II

Dissolution

geographic scales - local (water mass), regional Antarctica, global
temporal scales - days, seasonal, long term
tools - concentration, sediment distribution, biochemical, dissolution index, SEM (loss of taxonomic characters, loss of species, cell fragments, undersaturation of silica)
factors- productivity, temperature, sedimentation rate, upwelling, ocean circulation (surface and deep), temperature, valve shape, volcanic ash
biological record - valve morphology, species composition
geological record - presence and composition of assemblage

Numerous opinions were expressed with regard to dissolution as a limiting factor. A majority of individuals suggested that although silica is a limiting factor, neither silica nor silica dissolution is a limiting factor in the Southern Ocean as silica is generally available. While dissolution plays a critical role in influencing what is recorded in the biological and geological records, dissolution on its own will not regulate diatom species or assemblages.

Dissolution also plays a major role in valve morphology and its impact on species concepts. In addition, recent workers have suggested that diatom assemblages in the geological record may be misinterpreted. What was previously thought to represent a flora response to climatic change may actually represent a change in the degree of dissolution.

Further studies are required to document the role of dissolution in geological and biological records. Studies are also required to address the impact of dissolution on valve morphology and thus on geological species concepts.

Competition

geographic scales - local through water mass (regional)
temporal scales - days through seasonal
tools - abundance experimentation field work/laboratory study comparative growth rates
factors - physical environments, competition for space/light/nutrients, selective grazing
biological record - species diversity

There was minimal discussion on this topic. One question asked if laboratory studies could be applied to field studies?

Grazing

geographic scales - local through regional
temporal scales - days through seasons
tools - video, grazing/feeding experiments, problem with cell fragments
influences - valve size and structure, relative abundances, nutrients, dissolution, and sedimentation

This topic was not discussed in detail. Important questions for future study include:
1) Do zooplankton selectivity graze phytoplankton?
2) Are size and shape of preys important?

GROUP III

Phytoplankton and zooplankton production

geographic scales - local through regional
temporal scales - days through weeks, years (and climatic cycles)
tools - ^{14}C, cell counts, O_2 production, fluorometer
factors - meteorological, oceanographical, and biological processes
influences - biological cycles, food web

Minimal discussion occurred concerning this topic. Production of phytoplankton and zooplankton as limiting factors may be better grouped under competition. Questions for further research include:
1) What is the importance of laboratory studies vs in situ measurements?
2) Are we learning anything about diatom production from ^{14}C measurements?
3) Should these experiments be more species specific?

Vertical stability and advection

geographic scales - local through regional
temporal scales - days through weeks (also climatic cycles)
tools -XBT's, profiling, physical oceanography
factors - density and temperature gradients, meteorological and oceanographic processes
influences - species composition and abundance, wind speed/direction
biological record - species diversity, bloom intensity in general

Although vertical stability and advection are both important limiting factors, they were ranked below those already discussed. Both advection and vertical stability are restricted to local or regional scales and most likely impact the assemblage at very short time scales such as days and weeks. These factors influence species composition and bloom intensity by affecting the availability of nutrients to a specific region thereby limiting production, bloom intensity, or bloom duration.

In the geological record the resolution of time scales is reduced from days through weeks to hundreds to thousands of years, thereby inhibiting the identification of limiting factors at finer scales. The response of ocean circulation to changing climatic conditions can be documented in the geological record, by changes in diatom assemblages. However, it is unlikely that specific events such as the onset of, or increase in, surface productivity as a result of destratification of surface and intermediate waters can be evaluated.

Questions for future research include:
1) During a particular bloom are there critical times when decreased vertical stability will have a particular effect?
2) How does advection influence transportation of particulate matter to the sea floor?
3) Is advection important in sediment assemblage records or has the literature recorded only the movements of isolated frustules not gross advection of entire assemblages to other regions?
4) Is advection negligible with respect to percent of the "true" assemblage?

Although the following factors were considered to have a minimal role as limiting or regulating diatom species in high latitudes, they play a critical role in the distribution of diatoms as a result of providing environmental requirements for development of surface productivity and diatom blooms. As such, they are included in the overall lists of limiting factors for completeness.

Wind
geographic scales - margins
temporal scales - days/weeks
tools - satellites, anemometer
influences - upwelling, small scale turbulence mixing
biological record - bloom intensity (species abundance)

Sea ice/Ice shelf
geographic scales - local/regional coastal upwelling
temporal scales - seasonal
influences- temperature, wind speed direction

Dilution
geographic scales - local (coastal), regional, global (ocean fertility)
temporal scales - seasonal
tools - sedimentation rates, current winnowing of sizes, cell counts
geological record - sedimentation process

Questions for future consideration include:
1) Can wind selectively sediment out species?
2) Do chain forms sink more easily after stirring than solitary paired cells?
3) Does wind play a part in post-bloom sinking?
4) Can sea ice/ice shelf assemblages be recognized in sediments?
5) Does depth of water influence which species reach the sediment?

Session 4: Mechanisms of Sedimentation

Leaders: **A. Leventer, Ohio State University, U.S.A.**
J.-J. Pichon, Université de Bordeaux 1, France

Speakers: A. Leventer, J.-J. Pichon, R.W. Jordan, P. Bodén, K. Watanabe, Y.I. Polyakova, D. Harwood

A. Leventer: General summary

The focus of this session was on sedimentation as the process linking biological and geological frameworks of diatom research. The large differences in temporal and spatial scales over which biological and geological forces act, create difficulties in bridging the gap between disciplines. For example, geological data can provide a perspective on generic concepts and evolutionary lineages for biologists and taxonomists. Conversely, in order for geologists and paleontologists to interpret the sedimentary record, they need to understand the modern processes which regulate diatom production and distribution.

In interpreting the sedimentary record, it is important to recognize that modern diatom production is limited by a number of interrelated factors including light, temperature, nutrients, and water column structure and stability. In addition, large, short-lived, spatially restricted blooms are a common feature of polar ecosystems. Can these temporal and spatial limitations be recognized in the sedimentary record? The acquisition of more year-round oceanographic data (production and flux data in particular) will enhance our understanding of the modern biological system and the influence of temporal and spatial variability of diatom production on the sedimentary record.

Within the sedimentary record, resolution of specific biological events may be quite difficult because of modification of the assemblage during descent to the sea floor. Processes which differentially alter the biocoenoses include dissolution, grazing, and advection. In the upper water column, dissolution of numerous fragile diatoms may dramatically alter the assemblage. The influence of grazing is complicated by size considerations. Frustules of large diatoms, e.g., *Corethron*, may be shredded by grazers, increasing their surface area/volume ratio and subsequent dissolution. Smaller diatoms, e.g., *Nitzschia cylindrus* and spores of *Chaetoceros*, may be relatively unaffected during passage through the guts of zooplankton. For these diatoms, incorporation into fecal pellets will result in greater sinking rates and probably enhanced preservation. As silt-sized particles, diatoms can be transported over long distances by relatively weak currents. The influence of advection has been documented by sediment trap work. In McMurdo Sound, transport of *Thalassiosira antarctica* from areas of open water primary production to deep water beneath fast ice has been noted (Leventer & Dunbar 1987) and in the Antarctic Peninsula region, the northeastward advection of *Chaetoceros* spores can be traced from shallow water traps in Gerlache Strait to deeper water traps in Bransfield Strait (Leventer, In press). Increased settling velocities through the formation of resting spores, the aggregation of particles, and mass sinking can play an important role in determining the quality of the sedimentary record.

Finally, we must recognize that the polar ecosystem is not uniform. Processes which dominate the Arctic system may be quite different from those dominating the Weddell Sea versus the Antarctic Peninsula versus the Ross Sea (Honjo 1990). The major objectives of this session were to 1) assess our understanding of sedimentary processes as they relate to diatoms, 2) identify the critical questions which remain to be addressed and answered, and 3) discuss new approaches and technologies which should be applied over the next several years. We hope that the questions and discussions provoked by the presentations in this session will help develop a direction for future diatom research with a view toward understanding the mechanisms of diatom sedimentation in various polar regions.

J.-J. Pichon: The influence of dissolution on surface sediment diatom assemblages

The effect of dissolution on surface sediment diatom assemblages and subsequent paleoenvironmental interpretations was discussed. This transfer function study was based on diatom data from 124 Southern Ocean core top samples. The results of factor analysis indicated that though dissolution is clearly evident in determining modern sediment assemblages, it is only one of several factors. Importantly, useful paleoclimatic information about surface water properties, e.g., summer sea surface temperatures, can be derived from compositional analysis (Pichon et al. 1987).

Questions which arose on this presentation include:
1. Does dissolution in the water column and/or at the sea floor destroy the diatom signal? Based on this study, covering a large portion of the Southern Ocean, both paleoceanographic and dissolution information is preserved in the sedimentary record.
2. How applicable are the results of experimental dissolution studies to processes occurring in the natural environment? For example, the experimental design of many dissolution studies calls for relatively rapid dissolution of diatoms at elevated temperatures and in basic solutions.
3. How can we design more realistic dissolution studies? Factors which must be considered include: length of the experiment, composition of the dissolution medium (artificial seawater, weak or concentrated base), temperature of the dissolution medium, and condition of the diatoms used in experiments (e.g., presence or absence of protective coatings, monospecific or natural assemblages).

R.W. Jordan: Nearly monospecific layers of diatoms in sediments from the northern Weddell Sea

In a core from Jane Basin, in the northern Weddell Sea, sedimentary layers up to 3 cm thick have been found. These layers contain abundant and well-preserved specimens of *Corethron criophilum*, a relatively fragile diatom usually found only as corroded fragments. Similar, though not correlative, diatom-rich layers also are found in a nearby ODP core, Site 697. The most likely scenario for deposition involves mass sedimentation of a diatom bloom followed by rapid burial. However, based on modern data for primary production and standing crop, it is suggested that vertical flux alone cannot account for the thickness of these bands. Horizontal advection within the water column may result in concentration of diatoms during settling. Accelerated sedimentation rates as a result of hydrographic funnelling and the importance of basin geometry with respect to sediment depocenters are also critical factors to be considered (Jordan et al., In press b). In addition, a distinct sequence of siliceous microfossils is noted. From oldest to youngest, the sequence changes from high relative abundances of *Eucampia antarctica*, to *Corethron criophilum*, to the silicoflagellate *Distephanus*, then *Chaetoceros* spores, and finally *Rhizosolenia*. In order to interpret the paleoceanographic information recorded by this sequence, we need more modern distributional data.

The following questions were brought up for discussion:
1. What are the factors responsible for the production, deposition, and preservation of nearly monospecific layers of diatoms in the sedimentary record?
2. What is the significance of the roles played by primary production, grazing (or lack thereof), hydrography, basin geometry, and regional bathymetry in producing mass sedimentation events?
3. What are the common morphological and/or physiological characteristics of the diatom groups which are found as nearly monospecific sedimentary layers (e.g., *Chaetoceros* spores, *Rhizosolenia*, *Thalassiothrix*, *Corethron*)? Enhanced preservation

of heavily silicified *Chaetoceros* resting spores is well understood, but preservation of lightly silicified cells of the other genera warrants further investigation.
4. How much time is represented by these layers? Does each layer represent a single season bloom or repeated bloom conditions over hundreds or thousands of years? One way to address this question is to study a modern analog for this type of deposition. On productive areas of the Antarctic margin, diatom-rich layers are found in sediments from inner shelf basins. New developments in dating technology and capabilities may allow us to resolve the length of time required for deposition of these layers.

P. Bodén: The interpretation of relative versus absolute diatom abundance data

Relative and absolute diatom abundance data from ODP Leg 104 Hole 642B in the Norwegian Sea were presented (Bodén, In press). These downcore data were compared with absolute diatom abundance data from DSDP Leg 86 Site 578 in the western North Pacific. Downcore patterns of absolute and relative abundances are often very different from one another, as relative abundances are additionally influenced by the concentration of other components of the assemblage within the sediment. Analysis of the relative abundances of diatoms can be used to assess changes in the composition of the assemblage, but without complementary absolute abundance data, the causes for compositional changes cannot be determined. The distinct differences in downcore trends brought up several questions concerning the types of data micropaleontologists accumulate:
1. What is the best way to assess downcore information, i.e., is it adequate to display downcore plots of relative diatom abundance in order to look at changes in community structure, or is it necessary to go through the very time-consuming process of producing absolute abundance data?
2. Is there a proxy measure of absolute diatom abundance data, e.g., a chemical measurement, which might be a lot easier and less time-consuming to produce? For example, what is the relationship between numbers of diatoms/gram sediment and % biogenic silica?
3. What different information is relayed by relative versus absolute abundance data?
4. In using transfer functions, should you use relative or absolute abundance data? Presently, relative data are used.
5. If you use absolute abundance data in transfer functions, what types of computational difficulties will you run into?
6. How applicable is core-top information (death assemblage) in transfer function studies, i.e., should you compare downcore data to living assemblage information?
7. What kind of temporal resolution can we expect considering limitations of dating, bioturbation, and low accumulation rates? How should these problems influence sample spacing and comparison of data between cores?

K. Wanatabe: Diatoms in sea ice, water column, and surface sediment samples from Lützow-Holm Bay

Quantitative floral analyses of sea ice, water column, and surface sediment samples from Lützow-Holm Bay, Antarctica, were presented (Tanimura et al. 1990). The samples were collected from March 1983 through January 1984 and display a great deal of seasonal variability. The most common diatoms in the sea ice were *Berkeleya* sp., *Eucampia antarctica*, *Nitzschia closterium*, *N. curta*, *N. cylindrus*, *N. lecointei*, *N. turgiduloides*, *Pinnularia quadratarea*, *Pleurosigma* sp., *Rhizosolenia alata*, and *Tropidoneis* sp. The strand ice assemblage was dominated by *Entomoneis kufferathii*, *Berkeleya* sp., *Nitzschia lecointei*, *N. stellata*, and *N. turniduloides*. The water column assemblage was composed primarily of several species of *Chaetoceros*, *Nitzschia curta*, *N. cylindrus*, *N. lecointei*, *N. turgiduloides*, *N. vanheurckii*, and *Porosira*

pseudodenticulata. *Nitzschia curta* and *N. cylindrus*, common in both the sea ice and the water column, were also abundant in the sediments, while other *Nitzschia* species, such as *N. kerguelensis*, *N. obliquecostata*, *N. separanda*, and *N. sublineata*, which were not common in the sea ice or the water column, were also found in the sediments. The concentration of more robust species in the sediment samples results from dissolution within the water column. In addition, lateral advection results in transport of *Nitzschia kerguelensis*, which is very rarely found in the overlying sea ice or water column, to Lützow-Holm Bay sediments (Tanimura et al. 1990).

The questions which resulted from this presentation include:
1. Given the under-representation of the sea ice flora in the underlying surface sediments, what can we use as a tracer of the historical extent of sea ice? Despite dissolution in the water column, both *Nitzschia curta* and *N. cylindrus* are relatively common in sediments which are deposited in areas strongly influenced by the presence of sea ice. These two species thus may be good indicators of paleo- sea ice extent.
2. How can we distinguish the relative influence of dissolution and advection in producing a sedimentary assemblage? Additional studies of this type are essential in interpreting the relationship between the modern sediments and modern oceanographic and climatic conditions.

Y.I. Polyakova: Diatoms from shallow Arctic seas

The research on Arctic shallow sea diatoms has more than a century-long history and yet the body of information on this group is rather scarce. The data pertain mostly to species composition and seasonal development of phytoplankton or sea-ice flora of diatoms. It is only recently that species composition and distributional patterns of their thanatocoenoses in the Arctic have commenced. A preliminary study involving over 200 surface sediment samples from all Eurasian arctic shallow seas has resulted in the definition of several diatom assemblages that bear a relationship to hydrographic and sedimentologic processes of Arctic seas.

Late Cenozoic diatom assemblages in the sea sediments of the North Eurasian coast have occasional distribution. Nevertheless the data obtained indicate that the employment of this class of algae is very promising for solving questions of Cenozoic stratigraphy as well as the paleogeographic evolution of the Arctic region as a whole. Through analysis of the stratigraphical occurrence of fossil diatom species, it is now known that most marine diatom assemblages of Northern Eurasia extend back as far as the Pleistocene. The most ancient fossil marine diatom assemblages have been recovered in the northern plains of the Chukchi Peninsula.

D. Harwood: A look toward the future of diatom research

This presentation resulted from consideration of many of the questions which were raised by the previous discussions, and consisted of several suggestions for future diatom research. From a geologist's point of view, ecological gradient data, which would be most useful for paleoceanographic and paleoglaciologic reconstruction, includes information on diatom distribution with respect to both water depth and ice gradients. Most modern distributional studies have concentrated on *either* shallow water *or* deep water assemblages. In addition, we need to consider the other types of data (e.g., textural) which can be used in conjunction with diatom data to evaluate paleoenvironments. The importance of large-scale, discipline-integrated modern ecological and distributional studies as compared to present-day oceanographic and climatic data is of primary importance as we look toward the future of diatom research.

Session 5: Ice-water Interactions

Leaders: M.A. De Sève, Université du Québec à Montréal, Canada
K. Watanabe, National Institute of Polar Research, Japan

Speakers: M.A. De Sève, R. Horner, A. Leventer, R. Ligowski, V.A. Nikolaev, K. Watanabe, R.W. Jordan, D. Harwood

M.A. De Sève: Introduction

Ice can be defined as an ergocline (energetic interface) that modifies physical processes in the water column by reducing surface water mixing and light penetration, changing under-ice salinity (by melting or brine drainage processes) and lowering water temperature at the ice-water interface. All these processes, associated with ice formation, work toward increased stability which is beneficial to biological production. This production refers to ice biota production which occurs in the ice or at the ice-water interface (i.e., in the ice skeletal layer), and phytoplankton production which occurs under the ice, at the ice-edge, or directly in open water.

The importance of physical factors as controlling mechanisms of biological production was put forward in a number of presentations. The instability of the ice substrate was shown to be responsible for reduced ice algal biomass in the Gulf of St. Lawrence, eastern Canada (M.A. De Sève). In the Antarctic, the method of ice break-up (rapid or slow melting process) was shown to affect the delivery of diatoms to the sea floor (A. Leventer). Fast melting, allowing for continuous shedding of biogenic material into the water column, could provide a seed stock of algae for open water production. The stability of the water column, due to the ice melting, was suggested as an essential condition for ice-edge or under-ice phytoplankton blooms (R. Horner). The physical accumulation of algae during ice formation was demonstrated for Antarctic frazil ice (R. Ligowski).

The controversial subject of the seeding of phytoplankton blooms by ice algae was most discussed. In Admiralty Bay, South Shetland Islands, Antarctica, the sea ice diatom bloom and the spring increase of diatoms in the plankton were separated in time and species composition (R. Ligowski). At Syowa Station, Antarctica, algal assemblages from the ice were different from phytoplankton assemblages, but a correlation was found between chlorophyll *a* in the ice and in the phytoplankton (K. Watanabe). The species composition of ice algal assemblages from the Weddell Sea was dominated by pennate diatoms, namely *Nitzschia* spp. (V.A. Nikolaev). The subject of ice algae and spring phytoplankton blooms was also reviewed (R. Horner). No final conclusions could be drawn from the presentations and the discussion that followed. It would seem that relationships between ice algae and phytoplankton are more likely found in the Antarctic than in the Arctic, due to the presence of frazil ice. Whether ice algae seed the phytoplankton or not is still a matter for speculation, although there is more evidence against it and it may depend on ice type (e.g., frazil or congelation) and depth of the water column (e.g., in shallow areas the ice algal bloom is often separated by time and species present). Recent studies suggest that differences in life stages could account for the existence of some species both in the ice or as ice edge phytoplankters (Fryxell 1989). This might be an important area for future research, specially since little is known of the life histories (vegetative cells and spore formation) of ice algae.

This session was ended with some geological considerations. It was shown that diatoms from sediments, e.g., *Nitzschia curta*, could provide information on the past extent of ice edges (R.W. Jordan). A warning was brought up about the fact that present conditions may not apply directly to past environments (D. Harwood).

R. Horner: Ice algae and spring phytoplankton blooms revisited

For seeding to occur, there must be 1) a high degree of similarity between ice and water column assemblages; 2) a seasonal pattern of incorporation of planktonic forms into the ice whose release must correspond to the development of planktonic populations; and 3) ice associated species must be viable and grow in the water column (Garrison et al. 1987). In addition, the water column must be stable so that vertical mixing is retarded and the growing ice algae can accumulate in the water column (Smith & Nelson 1985).

In the Weddell Sea, the same species have been found in both the ice and water column, with relatively few of the numerically important species being associated exclusively with either habitat (Garrison et al. 1987). Relative abundances are also similar, but the flora of new ice reflects that in the water more closely than that in the older ice, probably because new ice harvests cells from the water nonselectively, while differential growth in the ice changes the composition (Garrison & Buck 1985). The release of cells from the ice also corresponds with increasing numbers of cells in the water column and this includes not only diatoms, but flagellates and ciliates, as well (Garrison et al. 1987; Garrison & Buck 1989). There is some preliminary evidence that ice algal cells are both viable and able to grow in the water column (Garrison et al. 1987). Another possible seeding mechanism is from viable cells found in fecal pellets (Fryxell 1989).

In the Arctic, planktonic species tend to be trapped on the underside of the ice forming a sub-ice assemblage at the outer edge of the ice in spring. The cells grow and multiply for one-two months before growth can occur in the water column. When the cells are released from the melting ice, they initiate the spring bloom at the ice edge at a time when too few cells are present in the water column to account for the explosive growth necessary for the bloom to occur (Syvertsen 1990).

In shallow arctic areas, the spring bloom in the water column is clearly separated by time and species from the ice algal blooms (Horner 1984; Grainger 1979). In southeastern Hudson Bay, ice algal residence time in the water column was long, grazing by herbivores in the water column high, and only about 10% of the production sank to the bottom, suggesting that most of the ice algal production remained in the pelagic system (Tremblay et al. 1989). This agrees with earlier work in the nearshore Chukchi and Beaufort seas where few ice algal cells were found in the sediments (Matheke & Horner 1974; Horner & Schrader 1982).

Differences between studies may be attributed to different methods used to assess the activity of the cells released from the ice, e.g., visual observations of cell health, cell fluorescence, etc.; differences in time of sampling relative to the sequence of melting and release of cells from the ice/stratification/phytoplankton blooms; or perhaps no real phytoplankton bloom was present (Demers et al. 1986). In addition, geographic location, ice type, and regional environment must be considered (Horner 1984).

A. Leventer: Control on production of diatoms in the sea ice: their delivery to the sea floor of McMurdo Sound, Antarctica

1. Controls on delivery:
The methods of ice break-up control the delivery of particulate matter from the ice to the sediments. In the eastern Sound, from late December on, ice thins precipitously until ice breakout in January or February. One-year ice melts at an average rate of 2.5 cm/day. This very rapid melting (4 days delivery), correlates with the advection of relatively warm water from the north.

In the western Sound, sea ice is on average thicker and does not thin appreciably, if at all, prior to its breakout in mid-February. Melting rates of 0.1 cm/day were measured in the southwestern Sound. The implications are that in the eastern Sound, biogenic material previously trapped in sea ice is continuously shed into the water column while sea ice is rapidly thinning. This may provide a significant amount of carbon and silica to the sediments in this region as well as a seed stock of algae for open water production. In the western Sound, the amount of melting prior to breakout may be inconsequential, but particulate matter may be carried away more easily during ice breakout, and possibly result in removal of seeding algae from the ice.

2. Limits on production:
Data on C/N ratios and assemblages show a general increase at most sites with largest increase at stations 12-15. This could indicate that nitrogen becomes a limiting nutrient for ice algal growth during the peak light period. There is also the possibility that the increase in C/N ratios is due to changes in the species present. But in Inner Debenham Canyon, no major change in diatom assemblages was observed through the season. The assemblages are dominated by *Entomoneis* sp. (cf. *oestrupi*?) which accounts for 70% of the species composition. The variations in C/N ratios do not correlate with variations in assemblages. At Tent Island, changes in assemblages throughout the season are observed, but specific changes in assemblages do not correlate with variations in C/N ratios.

R. Ligowski: Plankton and sea ice diatoms in the vicinity of the South Shetland Islands

Seasonal studies in Admiralty Bay and spatial studies in the northern boundary of pack ice in the Atlantic Ocean near the South Shetland Islands carried out during three Polish Antarctic Expedition indicate that:
1. Blooms of sea ice diatoms depended to a high degree on temperature.
2. Only a small part of the sea ice was discoloured by diatom blooms.
3. The density of diatoms in freshly formed frazil ice was almost equal to the density of diatoms in discoloured pancake ice and ice cakes, and exceeded the density of diatoms in the adjacent water by five times. This fact confirms the hypothesis about the physical accumulation of algae during sea ice formation. The density of diatoms in discoloured sea ice exceeded the density in the adjacent water by 600 to 2500 times. Principal growth of diatoms in sea ice is considered of a biological nature.
4. A high concentration of sea ice diatoms was recorded when diatoms were sparse in the plankton. Sea ice diatom blooms and the spring increase of planktonic diatoms were separated in time.
5. The highest biomass of diatoms was found in shore ice, drifting ice floes had lower biomass and fast ice had the lowest.

6. A dendrogram of similarities in species composition distinguished between two groups of stations: net phytoplankton and sea ice, indicating that sea ice diatoms and planktonic diatoms form separate assemblages.
7. Several assemblages of sea ice diatoms were found.
8. Species occurring in higher frequency in the plankton or the sea ice were distinguished.

V.A. Nikolaev: Communities of ice algae from Antarctica

The taxonomic composition, vertical and horizontal distribution of diatoms and other algae, living or found in different sea ice in late winter were investigated during the Weddell Gyre Study in 1989 on board R/V *Polarstern*.

Aboard the ship, 61 diatom taxa, 3 species of siliceous cysts, and 3 species of other groups of algae were identified. The very small pennate diatoms were not identified at the species level and some other diatoms have been identified at the generic level only. The dominant and subdominant algae were represented by 32 diatom taxa and 2 species of siliceous cysts.

The taxonomic composition of the ice algal assemblages was different. Diatoms were dominant in most ice samples. Species of the genus *Nitzschia*, including the section *Fragilariopsis*, were predominant as compared to other groups. On a few occasions, species of the genera *Chaetoceros* and *Dactyliosolen* were observed in the interior ice, in the middle part of a transect, as subdominants. In the interior ice of the northwest region of the Weddell Sea, siliceous cysts were dominant or subdominant.

Diatom assemblages of infiltration ice and meltwater under snow were also observed. Living cells of *Nitzschia cylindrus*, *N. closterium* and *Tropidoneis glacialis* were predominant. This assemblage lived in a salinity of 30-130. The number of cells in this assemblage reached 1.9×10^5/ml, ten times more than the number of cells/ml in the interior ice. Little is known about diatoms living in the inflitration layer at the snow-ice interface in winter. The abundance of diatoms in this layer was observed at many stations during winter. That may be the result of intensive biological processes taking place in conditions of low temperature and high salinity.

Siliceous cysts have been found in other areas in the Antarctic, e.g., in winter ice and open water north of Syowa Station (Takahashi et al. 1986). In pack ice near Mirnyy Station, in January 1988, very numerous cysts were found in the interior ice before the beginning of diatom growth (unpubl. data). Comparisons of all data show that siliceous cysts are probably widespread in the winter pack ice in the Southern Ocean.

In a previous study on ice algal assemblages in the Weddell Sea (Clarke et al. 1984), 33 diatom taxa and one species of siliceous cyst were identified using inverted and scanning electron microscopes. The total flora of winter ice in the Weddell Sea is probably composed of about 80-90 diatom species and 3-4 siliceous cyst species.

K. Watanabe: Seasonal variations in net plankton and ice algal assemblages in coastal fast ice near Syowa, East Antarctica

Diatom assemblages in the water column and sea ice were compared in the coastal fast ice area near Syowa Station (69°00'S, 39°35'E), in east Antarctica.

Interactions from the ice to the water column:

1) An increase of chlorophyll *a* concentration and pigment ratio in the water layer beneath sea ice was observed in September-October when ice algae grew in the bottom ice layer. This suggested an input of microalgae from the ice to the water column. 2) When the ice melted in spring-summer, ice assemblages were released to the water column. Dominant species in the bottom ice assemblages of the area studied, i.e., *Entomoneis kufferathii*, *Nitzschia* spp. (in the section *Fragilariopsis*), *N. lecointei*, and *N. stellata*, were also collected from the water column beneath the ice in mid-December and mid-January, suggesting the input of microalgae from the sea ice to the water column. However, the dominant species of the summer bloom in the water column (*Chaetoceros* spp.) were not found growing in the bottom layer of the ice. Detailed studies with more frequent sampling of ice and water are needed to clarify whether sea ice assemblages are seeding the phytoplankton bloom in the sea ice area.

Interactions from the water column to the ice:
1) Incorporation of microalgal flocs into sea ice in autumn was observed. Similarity of the species composition in the flocs to that of bottom ice assemblages, especially to sub-ice assemblages, suggest recruitment of ice assemblages from the water column, when ice develops. 2) Planktonic diatom species, e.g., *Rhizosolenia* spp., which were rarely found growing in the bottom ice layer, were observed trapped in the interior ice layer in autumn. But they did not grow since the chlorophyll *a* standing crop in the ice layer did not increase significantly. 3) In the bottom ice layer, certain species grew with the development of sea ice in autumn-winter and formed a dark discoloration in the bottom ice in spring-summer.

M.A. De Sève: Structure and composition of ice algal assemblages from the Magdalen Islands

Sea ice characteristics were studied in relation to nutrient dynamics, biomass and community structure and composition of ice algal assemblages from the Magdalen Islands area, Gulf of St. Lawrence. Brine volumes, estimated from measured ice temperature and salinity, allowed the determination of salinity within brine cells. The instability of the ice substrate was demonstrated with respect to the short duration of the ice cover (8 weeks), ice melt, and rafting processes.

The study of nutrient dynamics in ice and seawater suggested silicate and nitrogen limitation at landfast ice stations, but no correlation was found between ice algal biomass and nutrient concentrations.

Two types of ice algal assemblages were observed. The first type is similar to that found in Arctic landfast ice algal assemblages with a majority of pennate forms. The dominant species were: *Nitzschia cylindrus*, *N. polaris*, and *Navicula kariana*. The second type, rarely described for the Arctic or the Antarctic, is composed of a high percentage of centric diatoms (abundance > 46%), with *Thalassiosira nordenskioeldii* as the dominant species. The second type was related to drifting pack ice assemblages.

Special session: Computerized micro-organism counter
Leader: P.B. Hamilton, Canadian Museum of Nature, Canada

With the introduction of computers into research activities, it became apparent that there was a more efficient way of collecting quantitative data for ecological study. Jackson et al. (1984) first published the software for the plankton counter using a

programmable calculator that contained the language "BASIC". Specifically, this language used a command called "INKEY", which allowed the computer to interpret the depression of a fixed alphabetic/numeric key and remembered the key that was depressed. With the use of this command, the keyboard become an instant counter, similar to the multi-channel mechanical counters available on the market. Upon completion of a count with the "computer" counter, the data could be saved as a file and transferred to a larger computer for further analysis. The advantages to this new counter included, the elimination of data transfer from paper to computer, and an option for correcting errors in counts.

Lately, a new version of the counter was published with many additions and changes (Hamilton 1990). The counter software was expanded to IBM and APPLE computers and major improvements were made. The new counter offers phytoplankton, periphyton, benthic diatom and zooplankton counting. Further, the software automatically calculates cell/frustule densities, cell biomass, produces size fractionation summaries, and checks for and calculates counting error. Additional options include count recalculations and a simple line editor for ASCII files. Version 2.7 of the software runs from a master menu linking all the programs for easy access and data manipulation.

In conclusion, the use of computerized counters will reduce human error, improve counting accuracy and enhance efficiency in environmental research.

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THIRD POLAR DIATOM COLLOQUIUM
LIST OF PARTICIPANTS

Baldauf, Jack
Ocean Drilling Program
Texas A&M University
College Station, Texas 77843
U.S.A.
Telephone: 409-845-9297

Bérard-Therriault, Lyse
418 Le Bourgeois
Pointe-au-Père, Québec G5M 1N6
Canada
Telephone: 418-722-9385

Bodén, Per
Department of Geology and Geochemistry
University of Stockholm
S-106 91 Stockholm
Sweden
Telephone: 46-8-164894
Fax: 46-8-345808

De Sève, Michèle A.
GEOTOP
Université du Québec à Montréal
C.P. 8888, Succursale A
Montréal, Québec H3C 3P8
Canada
Telephone: 514-987-7019
Fax: 514-987-3635

Ferrario, Martha E.
División Ficología
Facultad de Ciencias Naturales y Museo
Universidad Nacional de La Plata
Paseo del Bosque s/n°
1900 La Plata
Argentina
Telephone: 21-43694

Gilbert, Neil S.
British Antarctic Survey
High Cross
Madingley Road
Cambridge CB3 0ET
United Kingdom
Telephone: 0223-61188
Fax: 0223-62616

Håkansson, Hannelore
Department of Quaternary Geology
Lund University
Tornavägen 13
S-223 63 Lund
Sweden
Telephone: 46-46-107888/125636
Fax: 46-46-104830

Hamilton, Paul B.
Botany Division
Canadian Museum of Nature
P.O. 3443, Station D
Ottawa, Ontario K1P 6P4
Canada
Telephone: 613-990-6531
Fax: 613-990-6451

Harwood, David M.
Department of Geology
University of Nebraska-Lincoln
Lincoln, Nebraska 68588
U.S.A.
Telephone: 402-472-2648

Horner, Rita
School of Oceanography, WB-10
University of Washington
Seattle, Washington 98195
U.S.A.
Telephone: 206-543-8599
Fax: 206-543-6073

Jordan, Richard W.
Geophysics Division
British Antarctic Survey
High Cross
Madingley Road
Cambridge CB3 0ET
United Kingdom
Telephone: 0223-61188
Fax: 0223-62616

Kingston, John C.
Department of Biology
Queen's University
Kingston, Ontario K7L3N6
Canada
Telephone: 613-545-6193
Fax: 613-545-6617

Lapointe, Martine
GEOTOP
Université du Québec à Montréal
C.P. 8888, Succursale A
Montréal, Québec H3C 3P8
Canada
Telephone: 514-987-4080

Leventer, Amy
Byrd Polar Research Center
Ohio State University
125 South Oval Mall
Columbus, Ohio 43210
U.S.A.
Telephone: 614-292-6531
Fax: 614-292-4697

Ligowski, Ryszard
Laboratory of Polar Biology
Institute of Environmental Biology
Lódz University
Banacha Street 12/16
PI-90-237 Lódz
Poland
Telephone: 836-45
825-52

Medlin, Linda
Department of Botany
University of Bristol
Woodland Road
Bristol BS8 1UG
United Kingdom
Telephone: 44-272-303763
Fax: 44-272-732657

Nikolaev, Vladimir A.
Komarov Botanical Institute
Academy of Sciences of the USSR
2 Prof. Popov Street
197022 Leningrad
U.S.S.R.
Telephone: 812-234-5410

Pichon, Jean-Jacques
Département de Géologie et d'Océanographie
U.R.A. CNRS 197
Université de Bordeaux 1
Avenue des Facultés
F-33405 Talence
France
Telephone: 56-806800
Fax: 56-370774

Polyakova, Yelena I.
Geograpgical Faculty
Moscow State University
117234 Moscow
U.S.S.R.
Telephone: 939-2830

Poulin, Michel
Division de la botanique
Musée canadien de la nature
C.P. 3443, Succursale D
Ottawa, Ontario K1P 6P4
Canada
Telephone: 613-990-6454
Fax: 613-990-6451

Stockwell, Dean A.
Marine Science Institute
University of Texas at Austin
P.O. Box 1267
Port Aransas, Texas 78373
U.S.A.
Telephone: 512-749-6702
Fax: 512-749-6777

Wasell, Anders
Department of Quaternary Research
Kvartärgeologiska Institutionen
Odengaten 63
S-113 22 Stockholm
Sweden
Telephone: 46-8-164885

Watanabe, Kentaro
National Institute of Polar Research
9-10, Kaga 1-chome
Itabashi-ku
Tokyo 173
Japan
Telephone: 813-962-4711
Fax: 813-962-2529

Zielinski, Ulrich
Alfred-Wegener-Institut für Polar- und Meeresforschung
Columbusstraße
Postfach 12 01 61
D-2850 Bremerhaven
Germany
Telephone: 471-4831-232
Fax: 471-4831-149

LIST OF PREVIOUS PARTICIPANTS TO THE FIRST TWO POLAR DIATOM COLLOQUIA

Abelmann, Andrea
Alfred-Wegener-Institute für Polar- und Meeresforschung
Columbusstraße
D-2850 Bremerhaven
Germany

Bartsch, Annette
Alfred-Wegener-Institute für Polar- und Meeresforschung
Columbusstraße
D-2850 Bremerhaven
Germany

Fryxell, Greta A.
Department of Oceanography
Texas A&M University
College Station, Texas 77843
U.S.A.

Furuya, Ken
Ocean Research Institute
University of Tokyo
Minamidai, Nakano
Tokyo 164
Japan

Gersonde, Rainer
Alfred-Wegener-Institute für Polar- und Meeresforschung
Columbusstraße
D-2850 Bremerhaven
Germany

Hasle, Grethe R.
Department of Biology
Marine Botany
University of Oslo
P.O. Box 1069 Blindern
N-0316 Oslo 3
Norway

Hellum, Cecilie
Department of Biology
Marine Botany
University of Oslo
P.O. Box 1069 Blindern
N-0316 Oslo 3
Norway

Karpuz, Nalân Koc
Geologisk Institut Avd. B
University of Bergen
Allegaten 41
N-5007 Bergen
Norway

Kellogg, Davida
Institute of Quaternary Research
University of Maine
310 Boardman
Orono, Maine 04469
U.S.A.

Klöser, Heinz
Alfred-Wegener-Institute für Polar- und Meeresforschung
Columbusstraße
D-2850 Bremerhaven
Germany

Labracherie, Monique
Département de Géologie
Université de Bordeaux
Avenue des Facultés
F-33405 Talence
France

Lange, Carina
UCSD-Scripps Institution of Oceanography
A-015
La Jolla, California 92093
U.S.A.

Oppenheim, Deborah R.
School of Biological Sciences
Portsmouth Polytechnic
King Henry I Street
Portsmouth PO1 2DY
United Kingdom

Priddle, Julian
British Antarctic Survey
High Cross
Madingley Road
Cambridge CB3 0ET
United Kingdom

Scharek, Renate
Alfred-Wegener-Institute für Polar- und Meeresforschung
Columbusstraße
D-2850 Bremerhaven
Germany

Scherer, Reed P.
Byrd Polar Research Center
Ohio State University
125 South Oval Mall
Columbus, Ohio 43210
U.S.A.

Schmidt, Roland
Limnologisches Institut der österreichischen Akademie der Wissenschaften
Gaisberg 116
A-5310 Mondsee
Austria

Schrader, Hans
Geologisk Institute Avd. B
University of Bergen
Allegaten 41
N-5007 Bergen
Norway

Syvertsen, Erik E.
Department of Biology
Marine Botany
University of Oslo
P.O. Box 1069 Blindern
N-0316 Oslo 3
Norway

Thomas, David P.
Department of Botany
University of Tasmania
G.P.O. Box 252C
Hobart
Tasmania 7001
Australia

van Iperen, Jolanda
NIOZ
17 goAB Den Burg Texel
The Netherlands